BIOLOGICAL RHYTHMS AND SHIFT WORK

SHIFT WORK AND THE WORKER

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Definition and Prevalence

To some, the terms "shift work" and "night work" are synonymous. The problem with such a restricted definition, however, is that it excludes very early morning and evening ("twilight shift") work hours which may in some cases be just as harmful (particularly in the social/domestic arena) as the infamous "graveyard" (night) shift. For the present purposes we shall therefore adopt Akerstedt and Gillberg's (1982) definition of shift work as any regular employment taken outside the "normal" daywork window of 7 AM to 6 PM

Using such a definition, one finds that approximately 20 million American (i.e., 22% of the workforce) are involved in shift work in one form or another (Mellor, 1986), although other authors (e.g. Czeisler et al, 1985) argue that this may be an underestimate. The 22% figure fits in fairly well, however, with the 20 to 25% figure quoted for Scandinavia, Western Europe and Japan (Akerstedt & Gillberg, 1982, Kogi, 1985).

The prevalence of shift work appears to be on the increase as more and more service industries provide evening and/or around-the-clock coverage, and as manufacturing industries require machines which are so expensive that 100% utilization is needed to make them cost-efficient. Moreover, social trends towards multi-income families have meant shift work exposure (e.g. in part-time evening work) for those who might, in earlier times, have been outside the conventional workforce.

Methodology

Shift work is not easy to study. Very often, the most important variables are those that occur outside the workplace, (e.g. day sleep quality), thus relying to a large extent upon the goodwill of the workers involved. Also, many of the measures are subjective and therefore capable of contamination by particular outcome expectancies (e.g. the move to increase shift pay differentials). There are three basic classes of study, which we shall denote "field studies", "survey studies" and "laboratory simulations".

"Field studies" are comparatively rare in the world literature (and largely absent in the U.S. literature) because of the high cost and political difficulty of getting hard physiological, production, and/or subjective measures from a group of workers for a reasonable period of time (e.g., one complete cycle of a rotating shift schedule). Such studies often have a small sample size and require a fairly dedicated group of volunteer subjects (and a tolerant and enlightened management) if circadian rhythm or sleep variables are to be measured properly. When carried out correctly, however, such studies provide an invaluable picture of what is happening to the sleep, circadian rhythms and performance of shift workers under various conditions. Classic field studies are those of Akerstedt (1988)(Sweden), Knauth and Rutenfranz (1976)(West Germany), Tilley et al (1982)(UK) and Reinberg et al. (1984)(France). The present author

has also been associated with some limited scale field studies (Folkard, Monk & Lobban, 1978, 1979; Folkard and M[redacted], 1981; Monk and Embrey, 1981).

Measures taken in field studies are in circadian, sleep, and mood/performance domains. Body temperature is the preferred variable in the circadian domain because of its ease of measurement and stability in indicating the status of the circadian system. Ideally, sleep is measured polygraphically but this is usually impractical, and sleep diary measures have to suffice. Mood and performance (including subjective activation) are measured by interpolated tests, preferably augmented by measures of actual on-the-job performance.

Survey studies are considerably easier to do, and usually involve the worker in sitting down answering questions for one or two interview or classroom-type sessions, with the data being augmented by personnel, health service and/or absenteeism file searches and a review of production figures. Neither circadian rhythm nor sleep diary measures can be obtained, and the best one can usually hope for such variables are questions regarding the average timing and quality of sleeps after the various shifts and levels of alertness on them. Survey studies are often carried out before and after an intervention in order to assess its impact. The best known of these is Czeisler et al's (1982) "Potash Mine" study in which the (positive) effects of a change in the speed and direction of rotation of a shift schedule were assessed. As always, contamination by Hawthorne (placebo) effects can endanger

the validity of such studies (Nachreiner, et al., 1977).

Laboratory studies attempt to simulate the shift situation in the laboratory. Some (e.g. Walsh, Tepas et al, 1982) use actual shift workers but many are forced to rely upon the conventional "healthy young men" (e.g. Knauth et al, 1978; Weitzman and Kripke, 1982). The major advantage of laboratory studies is to get clear and complete recordings of sleep and circadian rhythms (and interpolated mood and performance tests) without all of the noise and missing readings that are so characteristic of the field setting. The disadvantages (and they are major) are: that social and domestic factors are totally ignored, that the individual is not doing a real job, and that the situation only lasts weeks rather than years. As we shall see when the problems of shift work are discussed, these factors may severely limit the applicability of laboratory study findings. However, laboratory studies may be the only satisfactory way that sleep and circadian rhythms can be accurately measured.

From the preceding discussion it is clear that shift work research does not lie within the boundaries of one discipline, but relies upon the skills of physiologists, psychologists, physicians, sleep researchers and ergonomists among others. Teams therefore have to be multi-disciplined, and the results often appear in rather obscure journals.

Europe and Japan have benefitted from government sponsored independent shift work research groups that were able to give generic findings, published in the open press, and suitable for

many different applications. Here in the United States, most shift work research has been conducted on a consultancy basis by moonlighting academics. As a consequence, many of the findings remain proprietary and therefore unpublished, and the nation has rather little "home grown" shift work research database upon which to draw. As mentioned before, most published U.S. studies are survey studies, evaluating "average" sleep timings, subjective alertness, health and wellbeing either before and after a shift schedule manipulation (e.g. Czeisler, et al., 1982) or as a "snapshot" of a particular group of shift workers at a given time, (e.g. Tasto & Colligan, 1976 (food processors & nurses); Tepas & Mahan, 1989 (rubber & plastics workers); Lee, 1989 (nurses) in order to determine the demographic and/or trait characteristics associated with good or poor coping ability. The most notable exceptions to this trend are provided by the laboratory studies of Tepas et al (1981a, b), and Walsh et al (1984) both of which are described elsewhere in this report. It remains the case, however, that most research findings come form foreign sources which may vary in their applicability to the U.S. situation.

Problems Associated with Shift Work

The major biological problems associated with shift work can be summarized as "Having to work when you should be asleep and having to sleep when you should be awake" (Monk, 1986). The human being is essentially a diurnal creature whose biological clock ("circadian system") is naturally geared towards sleep and inactivity at night, and active wakefulness during the day.

Because of this, the vast majority of human society is structured under the expectation that work will be during the day, recreation in the evening and sleep during the night. Morning and evening rush hours are catered to by mass transit, prime-time TV , sports events, and social gatherings occur in the evening, and a quiet environment enforced at night. Strong social taboos, for example, protect a dayworker's sleep from 2 AM non-emergency phone calls, none protect a night workers sleep from 2 PM ones. Thus, from both sociocultural and natural points of view, the shift worker is very often fighting against the diurnal trends and attitudes that surround him or her.

Shift work can thus be considered as a stressor which may in some individuals and some situations lead to a failure to cope, and therefore, various problems in the domains of social/domestic harmony, health, safety and substance abuse. Rutenfranz et al. (1977) quote a study of 9000 shift workers as indicating that 20% had difficulty adapting to shift work. Applying that rate to the U.S. shift working population indicates that up to 400,000 American workers may be experiencing shift work coping problems. This percentage rises as one moves to the older age groups. In a study of an Austrian oil refinery, Koller et al. (1978) found that more than 80% of their sample expected to be unable to continue shift work right up until retirement.

These figures suggest a serious concern for the future. In the late 1990's the "Baby Boom" bulge in population will be approaching their fifties--an age at which shift work coping

problems can precipitally increase (Reinberg et al, 1981; Foret et al, 1981). It is therefore possible that a nation-wide "shift work coping crisis" will arise at the turn of the new century with overloaded health facilities and a shortage of people willing and able to fill shift work positions.

The "Stress and Strain" Model

In 1980, Colquhoun and Rutenfranz proposed a "stress and strain" model of how the various detrimental effects of shift work might arise. Broadly stated, this model asserts that such affects do not arise from the actual stress of shift work per se, but from the strain that develops within an individual who is trying to cope (more or less successfully) with all of the "unnatural" patterns of activity and sleep that shift work requires. Thus, there are intervening variables concerned with coping ability which will determine the level of harm experienced by the individual.

While the distinction between stress and strain might at first seem academic, in reality it is a vitally important one. It implies, for example, that if strain can be reduced (e.g. by the learning of new coping strategies) then even if the stress is the same (i.e., the shift system is unchanged), the level of difficulties (in the safety, health and social/domestic domains) might still be significantly reduced. That is not to say that shift schedules need not be improved (they most definitely should), but even if they cannot, then education programs and other countermeasures can still make a difference. Putting it in

concrete terms, the incidence of gastric ulcers and heart disease might be as much a function of the social support and educational network given or denied to the shift workers, as it is a function of the precise schedule they work.

The present author has developed a model (Monk, 1988) to explain how strain arises in the shift worker as a function of three basic areas of stress: circadian system, sleep and social/domestic (Figure 1). All three are interrelated, so that all three areas must be functioning well for strain to be entirely absent.

Strain from the Circadian System

Homo Sapiens is a diurnal creature with a circadian system designed to "expect" active wakefulness during daylight and restful sleep at night (Moore-Ede, et al., 1983). The circadian system is kept on track by an entrainment mechanism that uses "zeitgebers" (German for "time givers") coming from the environment (daylight/darkness) and behavior (social interaction, meal times etc.) of the individual. The entrainment mechanism is designed to accommodate the one hour or so "fine tuning" needed to keep the circadian system (whose natural period length is typically closer to 25h than to 24h) in tune with the 24h rotation of the earth. As a consequence, the process of adjustment to the abrupt changes in routine occasioned by commencing a run of night work is a slow one, typically taking well over a week (Knauth et al., 1981; Weitzman & Kripke, 1982; Monk et al., 1988). As well as the inherent inertia of the circadian system, there are

competing zeitgebers (eg daylight/darkness) working to slow down this adjustment process relative to that for jet-lag for example, where all zeitgebers are encouraging adjustment. Some researchers (Knauth et al, 1981) maintain that complete phase adjustment (re-alignment of timing) never actually occurs in shift work. Even in fixed shift night work (permanent systems), "weekends" off invariably allow a rapid reversion to the naturally favored diurnal ("day active") temporal orientation (Van Loon, 1963; Monk, 1986).

Apart from the sleep disruption discussed below, there are two major strains placed on the individual by a misaligned circadian system. The first strain arises because of the problem of "inappropriate phasing". Since a function of the circadian system is to "set the stage" for sleep at some times of day and wakefulness at others, a misaligned circadian system will disrupt both sleep and daytime functioning. Sleep will be disrupted by alerting mechanisms such as the cortisol surge and temperature rise. Night-time wakefulness will be impaired by temperature drops and melatonin surges (Akerstedt et al., 1982). In some tasks (particularly the monotonous ones such as driving, monitoring, and quality control) this can cause performance decrements which may severely compromise productivity and safety (Folkard and Monk, 1979; Monk and Folkard, 1985). Secondly, an inappropriately phased circadian system is in a state of disharmony, akin to a symphony orchestra without a conductor. That disharmony itself can result in feelings of malaise and

fatigue, as well as certain gastro-intestinal symptoms (Rutenfranz, et al., 1977; Czeisler, et al., 1983).

Different circadian strain will therefore be associated with different shift schedules. Ideally, from a circadian point of view, permanent night workers would form a "nocturnal culture" rapidly obtaining a nocturnal orientation to their circadian system and retaining that orientation during their days off. Although this is possible in certain isolated work sites and geographical locations, the overwhelming day oriented time cues (both social and physical) surrounding most night workers in the U.S. make this a largely unachievable goal. Reversion to a diurnal circadian orientation is all too easy, even during the two or three days of a "weekend-type" break (Van Loon, 1963; Monk, 1986). Achieving a nocturnal orientation can be likened to a salmon leaping up a waterfall. It is an arduous process to achieve a nocturnal orientation but all too easy to fall back down to day orientation.

In rotating schedules the strain is also primarily due to the re-entrainment process and to the circadian misalignment that is present until the re-entrainment process is complete. In mid-length rotations such as the weekly ones, complete re-entrainment may never occur, and the worker may find himself or herself in a perpetual "state of flux" with continuous circadian dysrhythmia, inappropriate circadian re-entrainment and severely impaired sleep and daytime functioning (Tasto and Colligan, 1978).

Rapid rotation accomplishes shift changes in sufficiently

rapid succession for circadian dysrhythmia to be absent (the circadian system remains resolutely diurnal), but the strain of inappropriate phasing still remains with potential for severe disruption of sleep and daytime functioning.

Strain from Sleep Problems

About 60-70% of shift workers complain of sleep disruption (Rutenfranz et al., 1985). A shift worker's sleep is disrupted by both endogenous and exogenous factors. Endogenous factors stem from the misaligned circadian system which has failed to prepare the body and mind for sleep and/or wakes the system up (e.g. to eat or use the bathroom) before 7 or 8 hours of restful sleep have been obtained. Often the worker will complain of being woken by exogenous factors (e.g. traffic noise, children playing) whereas in reality it is his or her misaligned circadian system that is the culprit (Folkard et al., 1979; Akerstedt, 1987).

Exogenous factors can be just as much a problem, however. As mentioned earlier, the shift worker's day sleep is considered to be much more "fair game" for disruption by domestic commitments (shopping, child care, etc.) than is the night sleep of dayworkers. Households are noisier during the day than at night, and much strain can develop from the chronic partial sleep loss that accrues. Very often, social and domestic disharmony (see below) can develop as the family gets blamed for sleep disruptions may not be entirely their fault.

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Social and Domestic Strain

As well as the strains related to sleep discussed above, shift work can often produce strain by preventing the worker from fulfilling various important family roles (Walker, 1985). Social companion, parenting, and sexual partner roles can all be compromised by shift work. Although a discussion of social and domestic strain is not within the present brief, it must be recognized: a) that such effects are major, and b) that they can severely impact mood, sleep, and circadian rhythms, therefore having indirect effects on safety and productivity.

Health Consequences of Shift Work Strain

Both the mental health and the physical health of the shift worker can be compromised by the strain of being unable to cope. (Moore-Ede and Richardson, 1985). Partly because the effects are largely unseen in those who are coping well, early studies (e.g. Taylor & Pocock, 1972) found increased mortality to be most evidenced in former shift workers who had had to transfer to a daywork job rather than in current shift workers (who to some extent comprise a self selected "survivor population"). Increased incidence of gastrointestinal disorders (including peptic ulcers) are the most often implicated (Rutenfranz et al., 1977; Baker, 1980; Czeisler et al., 1983). This makes sense in view of the obvious link between meal patterning and the circadian system, which has to suspend appetite and voiding in order to allow 7 or 8 hours of uninterrupted sleep. Risk factors associated with such disorders have also been shown to be higher in shiftworkers than

in dayworkers (Tarquini et al., 1986). The findings are also in accord with the typical grumbles of most shift workers who invariable complain of some form of "gut trouble" (Lee, 1989). Some authors (e.g. Harrington, 1978), however, ascribe those problems solely to poor meal choices and the absence of canteen facilities.

The other medical concern is cardiovascular disease. Earlier reviews (e.g. Rutenfranz et al, 1977) downplayed the importance of this, but recent research from Sweden (Knuttson et al., 1986) has demonstrated fairly convincingly that shift work is associated both with increased cardiovascular disease and with the risk factors associated with it (Orth-Gomer, 1983). Very recently, Ely and Mostardi (1986) have shown, in a study of Akron city police officers, that rotating shift work may be associated with high norepinepherine levels, placing one at higher cardiovascular risk.

Psychiatric disorders have yet to be studied properly using established diagnostic criteria. Self reported symptom checklists have indicated, though, an increase of neuroticism (Meers et al., 1978; Verhaegen, et al., 1982) and decrease of well-being (Akerstedt & Torsvall, 1978) in the shift work situation.

These findings are hardly surprising in view of the known links between circadian dysfunction and depression (Wehr & Goodwin 1980), and the commonsense view that someone who is getting too little sleep, is punch drunk from jet-lag and experiencing chronic domestic hostility is unlikely to be cheerfully well-adjusted.

There is also evidence that alcohol and substance abuse might

have a higher incidence in the shift work situation. In an analysis of the U.S. National Center for Health Statistics National Survey of Personal Health Practices and Consequences, Gordon et al. (1986) found that male shift workers reported higher rates of heavy drinking, job stress and emotional problems than did day workers. Female shift workers also reported higher rates of sleeping pill, tranquilizer and alcohol use. These problems may undoubtedly contribute to substance abuse at work, as well as in the home.

In conclusion, one must again include the caveat that those coping well may experience no adverse health symptoms at all. For those suffering from the strain of the situation, however, one might conclude colloquially "shift work is probably bad for the heart and the head and definitely bad for the gut."

Social/Domestic Consequences of Shift Work Strain

Marital problems, excessive domestic load and community alienation been documented as evidence of work strain. In a U.S. survey of 1490 hourly workers, Tepas et al. (1985) found an almost 50% increase in divorces and separations for those on (fixed) night work as compared to morning and evening shifts. When asked whether satisfied with the amount of time they had to spend with family and friends, both night and evening shifts were about half as likely to respond "yes" at their morning shift colleagues. Similar, or even worse, findings come from Europe and Scandinavia. In a 15 year longitudinal study of 504 Swedish papermill workers for example, Knuttsson et al (1986) found double the divorce rate

in shift workers as compared to day workers.

Excessive domestic load represents a major source of shiftwork coping differences and accounts for most, if not all, of the differences between the sexes in coping ability. Married women are often expected by their husbands to continue to run the household, raise the children, and do domestic chores in addition to their shiftwork burden (Gadbois, 1981). For these people there is usually insufficient "leisure" time available for such duties, and time is therefore "borrowed" from the sleep period. Thus Gadbois (1981) found that female night workers with two children slept about 9 hours less per week than their unmarried female colleagues.

Shift Worker Safety

While there are occasionally greater environmental risks associated with shift work, e.g., because of no daylight, or increased chemical exposure on 12h shifts, (Brief and Scala, 1986) these are usually outweighed by the reduction in human traffic. Indeed, when the accident rate is not expressed as a percentage of "traffic load", the number of accidents is often fewer on the night shift than on the others (Wojtczak-Jaroszowa & Jarosz, 1987). However, when accidents are expressed in terms of rate per worker on the job, the night shift often comes out worst (DeVries-Griever and Meijman, 1987). This illustrates the point that it is primarily the unadjusted shift worker who is the agent of risk, rather than the environment around the worker.

Probably the most quoted example of this is the "Three Mile

Island" incident which threatened a whole community and crippled an entire industry. This incident can be traced to human errors committed by weary shift working controllers mid-way through the graveyard shift (Ehret, 1981). Other accidents have a similar etiology, though, and abnormal hours of work and circadian dysfunction can often be blamed (Lauber and Kaysten, 1988).

There are a number of different ways in which maladjusted shift workers can become agents of risk to themselves and others. The first way is through sleepiness at work (Akerstedt, 1988), the etiology of which is discussed earlier. Sleepiness at work can lead to the problem of missed signals (e.g. a red light, a dial going critical), or of inappropriate responses to correctly perceived signals (e.g. landing on the wrong runway) as well as that of actually dozing off to sleep on the job. These effects are also important in the commute to and from work.

Although it is tempting to regard all dangerous shift workers as being overly sleepy, there are groups of maladjusted shift workers who are not sleepy at all, but who may be just as dangerous. These workers are too upset and angry to be sleepy, either for biological reasons (circadian dysfunction, sleep loss) or social ones (an imminent divorce). Such mood changes can lead to a cavalier (or directly aggressive) attitude towards the handling of dangerous machinery, and to the absence of concern for the safety of those around them.

The third means by which shift workers can become agents of risk is through simple performance decrements. Although not

subjectively sleepy, workers may be suffering performance decrements which (e.g. in meat packing industry) might lead to personal injury because of the critical nature of the work being undertaken.

Thus when talking about safety, as was the case for health, one is concerned primarily with the shift workers who are not coping for one reason or another, rather than the population of shift workers as a whole. Measures that either reduce the stress on the shift worker (e.g. by the adaption of more benign schedules) or the resulting strain (e.g. support systems and education) will undoubtedly improve safety both at the workplace and on the drive home from it.

Performance and Safety Consequences of Shift Work

While safety and performance are inextricably linked, it is quite possible for performance efficiency (and thus productivity and competitiveness) to be impaired without any additional safety risk necessarily occurring. Shift work performance, though, is a very complex issue. This complexity stems not only from the influence of task demands on both time-of-day effects in performance efficiency and the oscillatory control underlying them, but also from the influence of sleep deprivation effects, subjective and objective health effects, motivation effects (which will be influenced by social and family problems), and the effects of interindividual differences on both normal rhythm parameters, and the rate at which such parameters readjust to a change in routine.

Although it represents something of an oversimplification, the conceptual model of Folkard and Monk (19[redacted], which is illustrated in Figure 2 represents a useful framework in which to consider these effects. Essentially, this model (like the later one of DeVries-Griever and Meijman, 1987) reinforces the point that the 'on-shift' performance of the shiftworker is the product of many different factors, some interacting directly, others having their effect through changes in the adjustment process.

The three major inputs to the system are task demands (i.e. the levels of vigilance, physical and cognitive work required of the individual), the particular shift system used (very different effects spring from fixed (permanent) shifts than from rotating schedules, for example), and interindividual differences (including the worker's personality, age, health, sleep needs and behavior patterns [Moog, 1987]). These factors will then serve to affect the adjustment process in performance function (circadian performance rhythms), affective state (circadian rhythms in subjective vigilance and well-being), and physiological functions (sleep being the most crucial, but also the circadian rhythms in temperature and neuroendocrine function). The interaction of those adjustment effects will then influence the worker's on-shift performance, both directly and through indirect effects on his subjective health and well-being. Thus, one cannot simply assert that a nightshift performance will be poor because the worker is then 'at a low ebb'. That assertion may be quite wrong for some tasks, (e.g. Monk and Embrey, 1981) and certainly is

remiss in leaving out the sleep deprivation, health and motivational effects that can often outweigh the strictly circadian ones (DeVries-Griever and Meijman, 1987).

There are major problems in trying to determine intershift differences in 'real task' performance. The most important of these is the difference in working environments. Not only lighting levels, but also supervision levels, group morale, and distractions can all be very different indeed between nightshifts and dayshifts. Also, poorer performance can occur on the nightshift simply because there is nobody there to repair broken machines (Meers, 1975). Not only the work environment, but the work itself may be quite different on the nightshift. Very often particular parts of the job are actually saved for the nightshift, either because the process demands it (preparing things for shipment in the morning), or to make life easier for the nightworkers (e.g. long-running computer jobs held back in order to be run at night). Even in continuous-process operations, complicated development work may intrude during the day, but not at night (DeVries-Griever and Meijman, 1987).

Despite all these problems and complications, there are a few studies that have been able to obtain relatively continuous 24-hour 'real task' data, and indeed these studies show a remarkable similarity in time-of-day function (Figure 3). The six studies can be divided into three that actually measure the speed (Browne, 1949; Wojtczak-Jaroszowa and Pawlowska-Skyba, 1967) or accuracy (Bjerner and Swensson, 1953) with which the primary task is done,

and three that measure the consequences of lapses in attention or vigilance (Prokop and Prokop, 1955; Hildebrandt et al., 1974; Folkard et al., 1978). All six are in agreement in showing performance to be worse during the night hours, although in three of them there is also evidence of a pronounced post-lunch dip of almost equivalent magnitude. In a recent study of truck drivers (Hamelin, 1987) the risk of accident at midnight - 2 a.m. was found to be more than double the normal average.

Thus, it would seem reasonable to assert that, in general, nightshift performance is inferior to dayshift performance. However, as we have been careful to point out, there are a number of different ways in which nightshift performance can be degraded, not all of them directly circadian. Additionally, it is possible that differences in motivation level can differentially affect time-of-day functions. Khaleque and Verhaegen (1981) showed this in a comparison of cigar-making speeds between morning and afternoon shifts; significantly time-of-day differences only appeared in highly stressed workers who were making considerable efforts to gain extra piecework bonuses. Thus, it is possible that circadian effects can only 'show through' when workers are under pressure. In the absence of such pressure, nightworkers may be able to equate dayshift and nightshift performances because both are considerably suboptimal. In that case, overall inter-shift differences in productivity are more likely to occur form absenteeism and tardiness effects than from individual performance per se (Fischer, 1986; Farrell and Stamm, 1988).

Circadian Studies

An example of a field study using an interpolated task is provided by Wojtczak-Jaroszowa et al. (1978), who administered three very brief (1-minute) performance tests to ten shiftworkers on rotating morning, afternoon and night shifts. The tests measured manual dexterity, and simple and complex serial search performance, and were given just before the start of the shift, and again after 4 and 8 hours of work. All three tests showed the nightshift to have the worst performance. For the manual dexterity and simple serial search tasks, the morning and afternoon shift performance levels were roughly comparable, but for the more complex serial search task the morning shift was clearly the better of the two. All three shifts showed 'within session' declines that were equivalent in magnitude to the circadian effects.

Sleep Deprivation Studies

Although all studies of shiftworker performance must have circadian rhythms as a major area of interest, some studies have tended to focus on the sleep deprivation aspects, rather than the more strictly circadian ones. One of these is the 'work-sleep study' carried out by Tepas and his associates in Chicago (Tepas et al., 1981a,b). This comprehensive study brought actual shiftworkers into the sleep laboratory for polysomnography and performance testing while they continued to work, commuting from the laboratory rather than from home. Tepas et al. used a vigilance task presented just prior to bedtime, and a machine

paced additions test at bedtime and upon awakening. The subjects comprised ten nightworkers, ten dayworkers and ten (slowly) rotating shiftworkers who were working days or evening shifts at the time of being recorded. Nightshift workers were the group that performed worst on all three performances tests (there being no reliable differences between the other two groups). The performance differences were not accompanied by any equivalent differences in body temperature, but were correlated with the polysomnographic data in a way that was typical of a subject undergoing chronic partial sleep deprivation.

Rather than bringing shiftworkers in to the laboratory for polysomnography and performance assessment, Tilley et al. (1982) took the tests out to the field. Twelve shiftworkers were studied for one complete cycle of their weekly rotating shift system. The results were very similar to those found by Tepas et al., with day sleeps appearing to be disrupted and of shorter duration than night sleeps. As one would predict from circadian considerations, reaction speeds (both simple and multiple choice) were slower on the nightshift. However, there was also strong evidence for a night-to-night deterioration in performance, which the authors interpreted in terms of a build-up of partial sleep deprivation. They concluded that rapid rotation of shifts, with shorter runs of night duty, might be more conducive to better sleep and performance.

Supervision Levels

Anyone who has been a shift worker will attest to the freedom

and relaxed attitudes that can occur during the absence of dayworking management. Some shift workers can abuse that freedom, sleeping on the job, abusing drugs, shirking or performing non-job activities (e.g. running a card school). Productivity in those situations will inevitably suffer and one would be foolish not to address that issue before embarking upon some elaborate chronobiological intervention. The other side of the coin, though, is that many shift workers positively enjoy the lack of supervision, and given the proper motivation might be highly productive given the "esprit de corps" that shift work often engenders.

Overall Hazards to Worker and Public Safety and Well-being

In conclusion, one must realize that not only the worker, but also his or her family, and indeed the surrounding community, face hazards to their safety and well-being as a result of shiftwork. In evaluating these hazards one must again recognize the multifaceted nature of the shift work issue. At one extreme, there may be rare but highly significant events such as a near meltdown at a power plant, chemical plant explosion or train derailment. These highly visible events can affect (and indeed threaten) thousands of lives and have a massive effect on the wellbeing of surrounding communities. At the other end of the spectrum are the comparatively frequent events such as vehicular accidents on the drive home from work and minor injuries at work. Because of their lower profile in the news media, these events may tend to be relatively ignored. In dollars and cents terms (and,

indeed, overall human misery) it is quite possible, however, that the sum total of the frequent small events is as important to society as that of the occasional dramatic ones. Both are often the result of shift worker errors, and both should be factored in when society evaluates the cost effectiveness of shift work.

The Benefits of Shift Work

As Melbin (1978) and Scherr (1981) point out in their historical reviews, it is wrong to think of shift work as an entirely modern phenomenon. Even in ancient Rome, deliveries were required to be made at night in order to relieve traffic congestion, and for many centuries in almost all cultures, bakers of bread have been toiling through the last half of the night. With the industrial revolution, manufacturing processes evolved which simply could not be shut down at night, since the furnaces and kilns had to remain continuously at the correct temperature. Thus many of the fruits of technology we currently enjoy necessarily require shift work schedules.

In the service sector, too, shift work has enabled a significant improvement to be made in the convenience of daily life. Although health care has always been available (to a greater or lesser extent) on an around-the-clock basis, other services have only moved outside the "9 to 5" window comparatively recently. In particular, 24h shopping has made a dramatic change in people's lifestyles and, arguably, has encouraged the trend towards dual income families and decline in the number of full-time homemakers. Indeed, the flexibility in working hours allowed

for those who are part-time shift workers (who make up 42% of the shift work force or 8.3 million people [Mellor, 1985]) is a strong positive factor in the trend towards dual income families.

A major advantage of shiftwork in the domestic arena can be the child care (or other dependent person) coverage which it enables. Thus, if the husband and wife are on different shifts, then there is not a "coverage gap" during the day when they are both out at work. Although this might be unadvisable from a marital harmony point of view (see above) some workers do quote such arrangements as a significant benefit of shift work (Walker, 1985).

Double-jobbing or "moonlighting" is another activity which is facilitated by shift work. Depending upon one's point of view one can either regard this as an asset (allowing the worker to enhance his or her earning power), or a liability (producing safety, health and productivity concerns as total working hours are increased). Like the "baby sitting coverage" issue, though, this aspect of shift work is often viewed as an advantage when shift workers are surveyed. Mott et al. (1965) found twice as much double jobbing in night shift workers compared with dayworkers (23% versus 11%), and Maurice (1975) reported that 33% of continuous shift workers held second jobs. Very often the imposition of a new shift schedule by management (even to one more benign by chronobiological standards) may be resisted by the workforce simple because of its interference with double jobbing schedules.

In some cases the distinction between double jobbing and productive hobbies can be a hazy one. Thus the growing of vegetables, rearing of cattle or hunting of game might become a moneyspinner as well as an enjoyable pursuit. Whether for profit or simply for enjoyment, however, shiftwork does allow daytime activities that are infeasible on a standard daywork schedule. This become particularly true when twelve hour shifts are worked (Tepas, 1985), allowing longer blocks of "off duty" days. Many workers characterize these as a "vacation every three weeks" and enjoy them accordingly.

Melbin (1978) has nicely conceptualized shift work (or more particularly night work) as the opening of a new frontier. Thus much as the pioneers colonized the west, shift workers are colonizing the night. Just as the western frontier had a reputation for lawlessness, but a tradition of neighborliness and mutual help, so too does the night; a trend that was elegantly confirmed in a series of studies by Melbin. Just as there were many fine and noble aspects to pioneer life, so too may there be equivalent ones to the nocturnal lifestyle.

Countermeasures and New Technologies

Shift Work Schedules

The major advance made by the scientific study of human circadian rhythms has been the information it has given us regarding the suitability of otherwise of various shift work schedules The most important information concerns the rate of re-entrainment (phase adjustment) of circadian system to a change

in routine. Figure 4 illustrates the phase adjustment curve of the rectal temperature rhythm from two young male volunteers who worked 21 consecutive night shifts (Monk, et al. 1978). From this graph it is clear that at least 12 consecutive night shifts were required before complete phase adjustment occurred. Also important is the direction of phase shift that is being attempted. Temporal isolation studies which allow subjects to choose their own bedtime, waketime and meals ("free-running") invariably find that the human biological clock has a natural tendency to run slow, with a preferred period of around 25h, rather than the 24h of nature and society (Wever, 1979). Thus, under free-running condition bedtimes get progressively later by about one hour per day, a phenomenon confirmed by a tendency for people to go to bed later on weekends, rather than earlier. Perhaps because of this tendency to "run slow", the human circadian system appears to phase adjust more slowly to phase advances (60 minutes of phase change per day) than to phase delays (90 minutes of phase change per day) [Aschoff, et al., 1975; Klein, et al., 1972]. This would suggest that shift rotation in the forward direction (mornings, then evenings, than nights) would be more easy to cope with than rotation in the backward direction (nights then evenings then mornings). Although that prediction still needs to be properly tested in the field, there is some supportive evidence for it (Czeisler, et al., 1982).

There are a multitude of different shift schedules currently in use (Tasto and Colligan, 1978; Knauth and Rutenfranz, 1982).

Many of those systems approximate a "weekly rotation" whereby an employee works between 4 to 7 shifts at one timing before changing to another. This is particularly disheartening because most shiftwork experts agree that from a chronobiological point of view, weekly rotation is the speed of rotation is the most likely to produce problems (Akerstedt et al., 1977; Rutenfranz et al., 1977; Smith, 1979; Czeisler et al., 1982). Thus while there is insufficient time for the biological clock to re-align completely to the new temporal orientation, there is enough time to build up a sizeable sleep debt (Tilley et al., 1982). Between them, the circadian desynchronosis and partial sleep deprivation will inevitably result in malaise and on the job performance decrements.

Having decided upon the shift system or rota to avoid, it is less easy to decide upon the optimum alternative to select. Expert opinion here is divided. Most European and Scandinavian experts (e.g. Rutenfranz et al., 1977, Akerstedt, 1985) favour rapid rotation with very short (1 or 2 day) rounds of duty at one shift timing before moving to a different timing. In contrast, North American experts (Czeisler et al., 1982, Moore-Ede and Richardson, 1985) favour much slower rotation speeds, with three weeks or more at one shift timing before moving to a different timing. The controversy is discussed elsewhere in detail (Monk, 1986); essentially it revolves around the loss of nocturnal orientation during "weekend-type" breaks (Van Loon, 1963), and the relative levels of harm considered to be induced by "inappropriate

phasing" (having to work when the body and brain are geared to sleep) as compared to "circadian dissociation" (the breakdown in the harmony of all the various rhythmic processes).

One approach to resolving the issue is to consider the task the shift worker is being asked to perform. Different tasks not only show different "best" times during the circadian cycle, but also phase adjust at different rates to a change in routine (Folkard and Monk, 1979). Highly cognitive tasks involving working memory, mental calculations and verbal reasoning appear to peak earlier in the day and to phase adjust more quickly than the more simple repetitive or "automatic" tasks such as driving, quality control and monitoring.

In terms of performance demands, unadjusted (i.e. diurnally oriented) night workers are likely to find tasks involving serial search, inspection and/or the maintenance of vigilance (e.g. driving) to be particularly disrupted. Ample opportunity and circadian countermeasures designed to encourage circadian re-alignment should thus be concentrated on such workers. Shift rotation speed should be slow in the phase delay direction, so that a nocturnal orientation can be rapidly acquired and maintained (Czeisler, et al., 1982). Shift workers should be counselled to use sleep schedules and time cues (Zeitgebers) which will aid this process. In contrast, tasks involving immediate retention and high memory loads will be performed relatively well during the night shift, even in diurnally oriented individuals (Monk and Embrey, 1981). In these cases, therefore, rapidly

rotating shift systems (e.g. the "Metropolitan rota" of 2 mornings, 2 evenings, 2 nights and 2 days off) might be a suitable alternative. In such systems the circadian system retains its diurnal orientation, and a gradual build up of sleep loss over a long run of night duty is avoided (Tilley, et al., 1982). Whichever alternative schedule is selected, it should be remembered that there is now hard empirical evidence that significant improvements can accrue from a move away from a weekly rotating schedule, be it to a more slowly (Czeisler et al., 1982) or more rapidly (Williamson and Sanderson, 1986; Knauth and Kiesswetter, 1987) rotating system.

Management Education

The first major breakthrough required in management education is to convince a company's senior decision makers that a more enlightened approach to shift work will inevitably save the company money, making it more productive and competitive. As unemployment rates gradually fall, and hiring, selection, and training costs rise, it can make strong economic sense to have a contented and well-coping shift work force, than a poorly coping one with high turnover and absenteeism rates. Sometimes there is fear in the management that they will be forced into a radical restructuring of their whole shift working operation along "chronobiological principles". This is an unfortunate perception, because very often significant benefits can be gained with intermediate steps involving employee education and support services.

As in many other areas, the ultimate sanction against indifference in management to shift worker problems might be the legal one. It may well be that litigation from sick or injured shift workers becomes the means by which perceived harm is recompensed. Any worker taking that route would have no shortage of expert testimony to support the argument that shift work practices are by and large harmful. For example, The Shift Work Committee Japan Association of Industrial Health (1979) states "...in particular, the introduction of shiftwork for economic reasons related to accelerated depreciation of costly machinery or managerial efficiency must be prohibited." It is a sobering exercise to compare the different legislative attitudes to shift work between the U.S. and the rest of the world. This is particularly true of women (Singer, 1989) who are prohibited from night work (with certain exceptions) in many other countries (e.g. Belgium, Czechoslovakia, France, Germany, Italy, the Netherlands and Norway). Moreover, even when night work is not prohibited, legislation exists regarding hours in the working week (France [39], Brazil [36h]) and medical officer coverage (Austria). Overseas, the attitude to shift work is very different to that in the U.S.. Radical changes may take place, though, and the U.S. shift work employers of today might find themselves in the same predicament as the asbestos manufacturers of yesterday.

Scheduling Software

Prosaically, one reason for the relative simplicity of many shift systems, and their continued retention despite being

chronobiologically unsound is that they have been put together by middle or lower-level supervisors with few intellectual or information processing resources to help them. Recently, with the advent of personal computers and scheduling programs, it has become more feasible to move away from the more simplistic approaches. Some authors (e.g. Schwarsenau et al, 1986) have developed a whole shift schedule selection procedure involving computer programs that enhance the most chronobiologically acceptable features. Such systems (or their equivalent) are also available from some U.S. consultancies.

Employee Education

As mentioned previously, many of the problems of shift work i.e. the "strain" could be reduced by education and social support programs for shift workers. Indeed, much progress can probably be made simply by "awareness" programs which help shift workers to understand why they are having problems, and to reassure them that they are not weak, sick or in a bad marriage (Monk, 1988). When combined with a training program for coping strategies (such as is available from Matrices Consultants, Norwalk, CT) or Circadian Technologies, Boston Mass, for example), significant reductions in shift work strain will probably accrue.

Clinical Support

Clinical support specifically tailored for shift workers is largely lacking. This is unfortunate because they would undoubtedly benefit from "shift work clinics" where physicians, chronobiologists, sleep clinicians and family therapists could be

available to help those who are coping poorly. At the moment many U.S. shift workers with problems end up at sleep disorders centers. With a few notable exceptions, such centers are often sadly lacking in any knowledge of chronobiology and simply study the patient's sleep in order to arrive at a sleep disorders diagnosis (e.g. "schedule related insomnia") which may in some cases be unhelpful in that it suggests a disease or disorder where none is present, since it is perfectly natural for human beings to find it difficult to sleep during the day.

It would be more useful if sleep disorders centers could become sources of information on coping strategies and medical referral (e.g. to family therapists, substance abuse treatment, etc.), rather than mere laboratories where hapless shift workers have their sleeps recorded and diagnosis given. Sadly, only a few centers currently aspire to such goals.

Hardware

The role of hardware can be divided into the devices and techniques that facilitate research into the area, and those that seek to directly facilitate the individual shift worker's ability to cope. With regard to the former, the development of increasingly miniaturized electronics has allowed the field measurement of a number of different physiological parameters of the worker's circadian rhythms and sleep. The circadian rhythm of body temperature is the key variable most often studied, and there are commercially available systems which can be used to measure body temperature (as well as several other parameters) in an

ambulatory setting. The major problem with these systems is that they measure rectal temperature which although very accurate, is often resisted by subjects who dislike the notion of wearing a rectal temperature probe for several days or weeks at a time. Axilliary temperature (Motohaski, et al., 1987) has been tried as an alternative, with some success. many studies have used non-continuous measures of oral temperature instead (often special "easy to read" thermometers) and worthwhile data can often result (Knauth and Rutenfranz, 1976; Reinberg et al, 1984). Dahlgren (1981) has used a hybrid system with oral temperatures during wakefulness and rectal temperature during sleep.

A possible technological breakthrough as come from the recent FDA approval of a swallowable disposable "temperature pill" (distributed by Human Technologies (Cortemp) Inc., Florida) which transmits core temperature to a belt pack unit via an antenna worn in a special vest. Although a very recent development a number of researchers (including the present author) have found the device useful. Each pill is disposable and about 24 to 36 hours of data can be obtained depending upon the transit time through the digestory system.

The wrist activity monitor is an electronic device the size of a large wristwatch which is worn on the wrist of the non-dominant arm. It contains a motion sensor and makes a count of the number of movements made per predetermined epoch (typically 5 to 15 minutes) over an extended period of time (typically a week). The unit stores the information in its memory, which is then

dumped to a computer at the conclusion of the study. It is particularly useful for objectively recording temporal patterns of sleep and wakefulness. A recent example of its use is provided by Buck et al. (1989) who studied the sleep patterns of airline staff.

Sleep EEG monitoring in the shift worker's home has only rarely been undertaken (Tilley, et al. 1982). As well as portable EEG monitoring devices there is now available "telediagnostic" equipment which can transmit EEG data across the telephone lines to a polygraph in the laboratory. This fairly recent innovation is used at Pittsburgh to study the sleep of pregnant and post-partum women (Coble, pers. comm.) and has proven itself to be largely successful.

Other technological developments have the potential for <u>directly</u> ameliorating the shift work problem rather than indirectly doing so through the improvement of research protocols. The most important of these is the use of bright lights. Through the 1960s and 70s the dominant view of the circadian system was that it was largely unaffected by light/dark cycles except in as much as they influenced patterns of behavior (Wever, 1979). However, Lewy et al's (1980) demonstration that only <u>daylight</u> levels of illumination were sufficient to suppress endogenous melatonin production at night, opened up a whole new set of studies using daylight (>2000 Lux) levels of illumination in time isolation studies which had previously been concerned with comparatively dim artificial light.

The hormone melatonin is produced in the pineal and has been shown to be associated with tiredness when circulating in the blood stream (Akerstedt, et al., 1982). Thus, its suppression was thought to be important to the circadian system (Melatonin per se as a countermeasure is discussed below). Laboratory studies in both West Germany (Wever, 1988) and the United States (Czeisler, et al., 1986, 1989) have confirmed that bright lights can be extremely powerful as resetting agents (Zeitgebers) of the human circadian system. Wever (1988) has shown a dramatic increase in the range of entrainment (essentially equivalent to the "hours of phase shift per day" rate) when bright lights are used to stretch or shrink circadian "days". Czeisler et al. (1986) have shown in a Harvard study that 3 days of evening bright light exposure can delay the phase of the circadian rhythms of a woman suffering from advance phase sleep syndrome. Very recently Dr. Czeisler's group (1989) has derived a human phase response curve to bright light (with room light levels factored in), which suggests that phase resetting in the laboratory can be accomplished in three days if the timing of the light is appropriate (and if competing zeitgebers are either absent or ineffectual).

Applying bright light exposure therapy to shift workers has been the concern of Dr. Charmane Eastman in Chicago. By rigorous sue of goggles, light-proofed bedrooms and banks of bright lights, Dr. Eastman has shown that in some cases entrainment to non-24h routines can be attained by highly controlled bright light exposure (Eastman, 1987). However, most recently (Eastman, 1989)

she has concluded from a larger study that such procedures are at best only partial in their success. This largely negative conclusion is echoed by Moline et al.'s (1989) finding that ircadian rhythms in a simulated jet-lag study appeared to be, if anything, more disrupted by (post-shift) morning bright light exposure. Thus, while the theoretically oriented laboratory studies of bright light re-entrainment in humans are important and intriguing, their practical application for the shift worker may take some time to work out.

Medication and Drug Therapies

Since one of the major complaints of shift workers is that they obtain insufficient sleep, an obvious countermeasure is to improve that sleep by the use of hypnotic medication. There are two major problems of medication use, one of which has been solved, the other not.

The first problem with using hypnotics to improve daytime sleeps is that of residual or carry-over effects which leave the worker still drowsy in the evening and night when he needs to be alert. Such carry-over effects (which are characteristic of the barbiturates and longer-acting hypnotics) can exacerbate the sleepiness due to circadian effects (see above) leading to a potentially dangerous situation for the worker. Such problems have been to some extent overcome by the development of short-acting benzodiazepine's such as Triazolam (marketed as Halcion ®) which have a half life of only a few hours (Seidel et al., 1984). In a St. Louis study, Walsh et al (1984) nicely showed that fairly

large (0.5 mg) doses of Triazolam did indeed significantly improve the day sleep of night workers although this did not appear to result in any increased phase adjustment of the circadian clock relative to placebo. Thus after two nights of the drug, daysleeps 3 and 4 (with placebo) were no better than for those who had received placebo all the way through. Putative phase resetting properties of large doses of Triazolam in hamsters (Turek, and Losee-Olsen, 1986) now appear to have been due to changes in activity patterns of the animals (Turek, pers. comm.) rather than to anything more profound.

The second problem regarding the use of hypnotics by shift workers has most definitely not been solved, and is the reason why hypnotics are not recommended for this group (Monk, 1988). It relates to the chronicity of the shift workers problem. There has yet to be a hypnotic which is recommended for anything other than occasional transient insomnia. The shift worker's insomnia is frequent and chronic and the dual problems of tolerance and dependence imply that shift workers using hypnotics on a regular basis are probably deriving no benefit from them whatsoever and are only being deceived into thinking such drugs are effective by the "rebound insomnia" they experience upon withdrawal of the drug. Moreover, chronic high doses of Triazolam have in some cases been associated with mood changes, an effect to which shift workers are especially vulnerable. Until hypnotics developed which are totally benign in the chronic administration condition, it is infeasible that shift workers can achieve any lasting

benefit from such drugs.

Although a hypnotic may (in the short term) improve a shift worker's sleep what is truly needed is a "chronobiotic" (Simpson et al., 1973) which will facilitate a resetting of his or her circadian system. Although various substances (including Melatonin-see below) have been touted as chronobiotics the evidence is far from conclusive, and many experts (e.g. Reinberg, et al, 1987) conclude that a true chronobiotic has yet to be discovered. Apart from those drugs which are suspect because of their hypnotic properties (e.g. the benzodiazepines) which might render the phase shift more apparent than real, the prime candidate has been theophylline. Although there is some evidence of chronobiotic properties in rodents (Ehret, et al., 1975), in man the results have been negative, both in terms of careful controlled experiments at NASA-Ames (Connell pers. comm.), and in view of the fact that "millions of asthmatic patients consume rather large doses of theophylline daily to avert bronchospasm without complaining of jet-lag symptoms" (Reinberg, et al., 1987). It would therefore seem premature to assert that this drug has chronobiotic properties which would be of benefit to shift workers.

The oral administration of melatonin as a phase shift countermeasure does hold some promise in view of the obvious role of the hormone in the human circadian system. Arendt et al (1986, 1987) recently tried melatonin as a countermeasure in a small jet-lag study with some success, predominantly in subjective measures

of "jet-lag" and in circadian cortisol rhythms. No beneficial effects were found in body temperature or performance however.

Diet

As discussed previously in relation to health consequences, the diet of shift workers is generally inferior to that of dayworkers (Fisher et al., 1986) involving more snacking, more caffeine, more lipids and fewer hot meals. Dietary changes have been invoked by some authors (e.g. Harrington, 1978) as a reason for the increase in gastrointestinal complaints. Again, worker education programs can play a useful role in rectifying this, as can management interventions to provide adequate canteen facilities and/or vending machines. The Minnesota extension service has developed informational nutrition programs specifically for shift workers.

Some authors (e.g. Ehret, 1981) have put forward an elaborate diet-based feasting and fasting routine which is alleged to speed up the phase adjustment process, but many experts dispute its worth, and there is no hard evidence of its value in the shift work situation.

Fitness

Harma et al. (1988) have recently performed a study on 75 female shift working nurses which had the aim of determining whether improving levels of overall general fitness would allow better shift work coping ability. A 4 month exercise training program was implemented which had the effect of elevating VO_2 max levels by 7%. Improvements were noted in measures of sleep

length, night shift alertness and general overall fatigue. Physical fitness might thus facilitate shift work coping ability.

Overall Conclusions

Our overall conclusions regarding shift work and the worker can be divided into what is definitely true, what is probably true and what we still need to find out.

Definitely true is the fact that shift work can degrade the performance abilities, sleep, wellbeing, health and social life of individuals who are failing to cope. Also, the commonly used weekly backward rotating systems are likely to exacerbate these problems, and changes to a chronobiologically more benign system are likely to improve coping ability and therefore safety and competitiveness. Individuals who are advancing in age (>50y), are "morning larks", need more than 9h of sleep per day, or have an excessive domestic load are unlikely to cope well with shift work.

Probably true is the assertion that an aggressive employee education and support program regarding chronobiology, sleep hygiene, dietary, and family counselling, is likely to significantly improve the coping ability of shift workers and thus their safety and productivity. These strategies might include the use of bright lights and other manipulations designed to facilitate the circadian phase adjustment process.

What we still need to find out is the level of importance that should be placed upon circadian phase adjustment questions per se, and whether the phase delay direction is truly a superior direction of shift rotation (Turek, 1986). Also more research is

needed on the incidence of alcohol and substance abuse in shift workers, and whether shift work really does result in a reduced human life span.

In the late 1990's the U.S. "baby boom" generation will be approaching the stage of life at which shift work problems can greatly increase. At the moment, when compared to other countries we are sadly lacking in both protective shift work legislation and in the research that underpins it. Arguably, those deficiencies might significantly hurt our international competitiveness in future decades.

What the nation needs is 1) a U.S. program of shift work research which involves laboratory, field and survey studies which can be published in the open literature and generate findings applicable to many different facets of U.S. industry and commerce; and 2) a national strategy to provide education, counselling and treatment programs for shift workers that are appropriate to their unique situation, and cover the whole range of problems they encounter.

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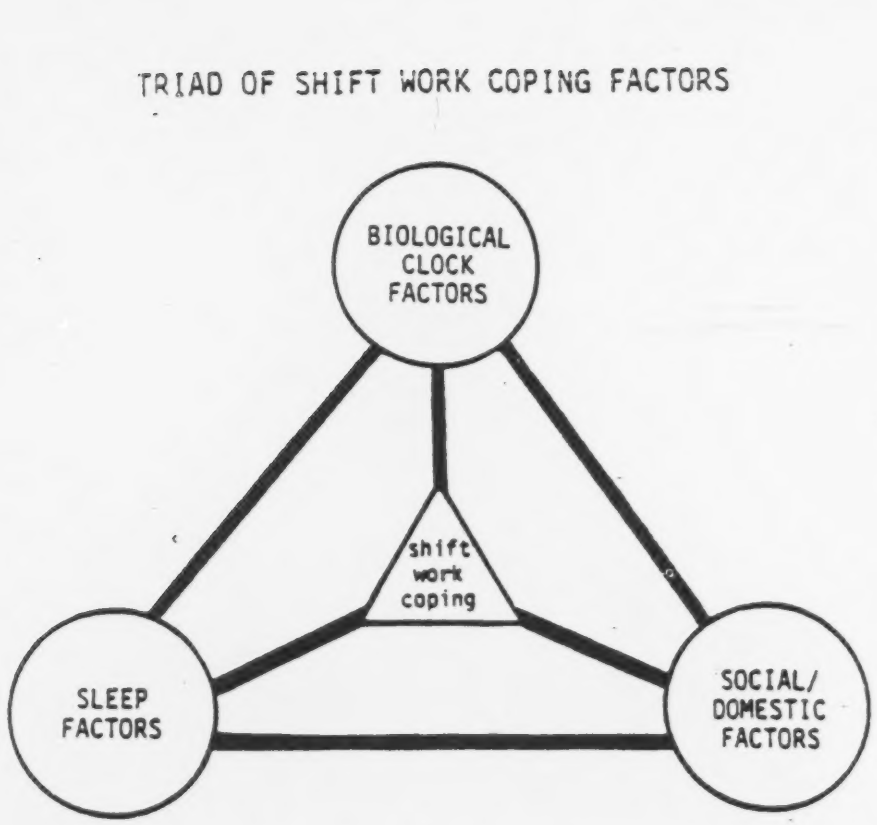

Figure 1. Schematic model of the triad of factors influencing shift work coping ability.

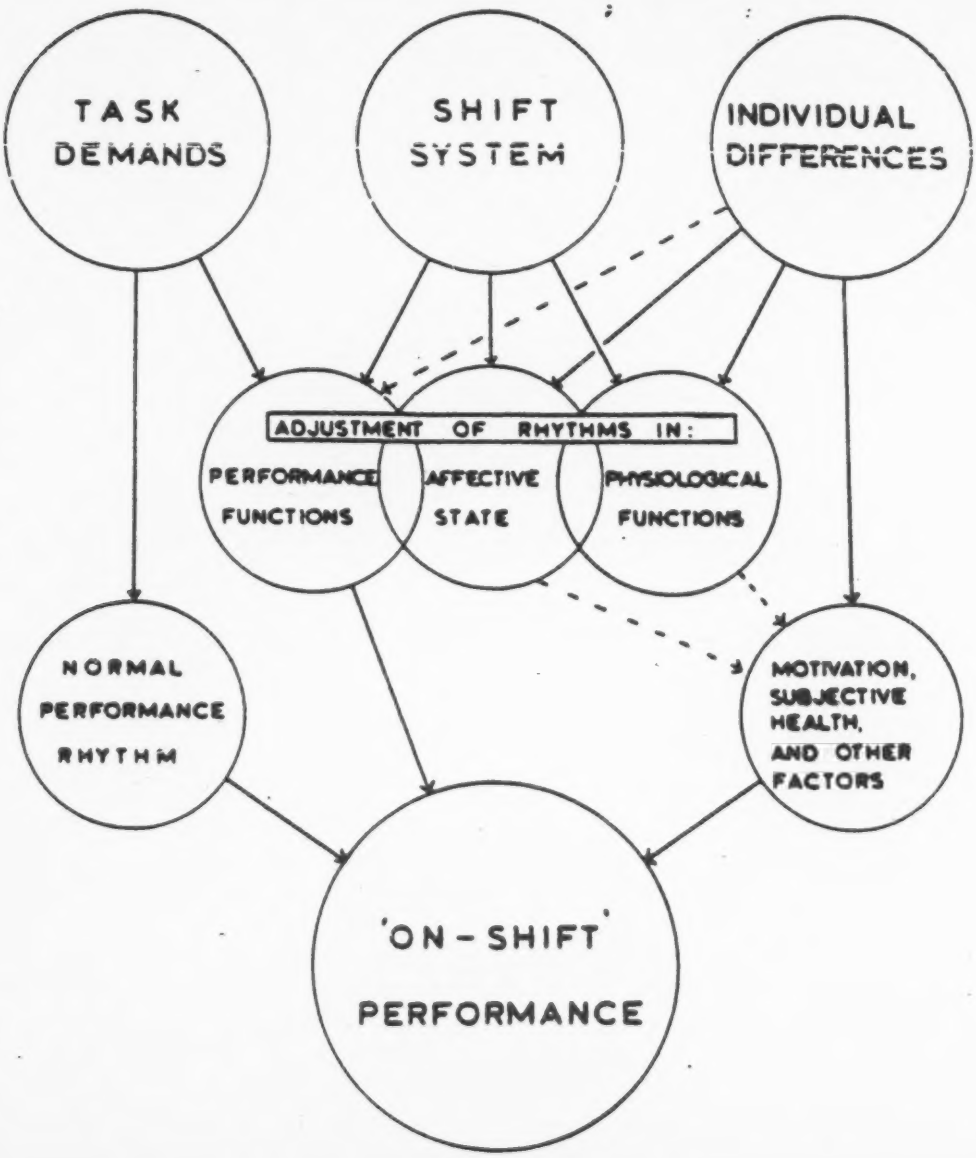

Figure 2 A conceptual model of the factors affecting 'on-shift' performance. Solid lines represent known influences, and dashed lines probable ones. From Folkard and Monk (1979)

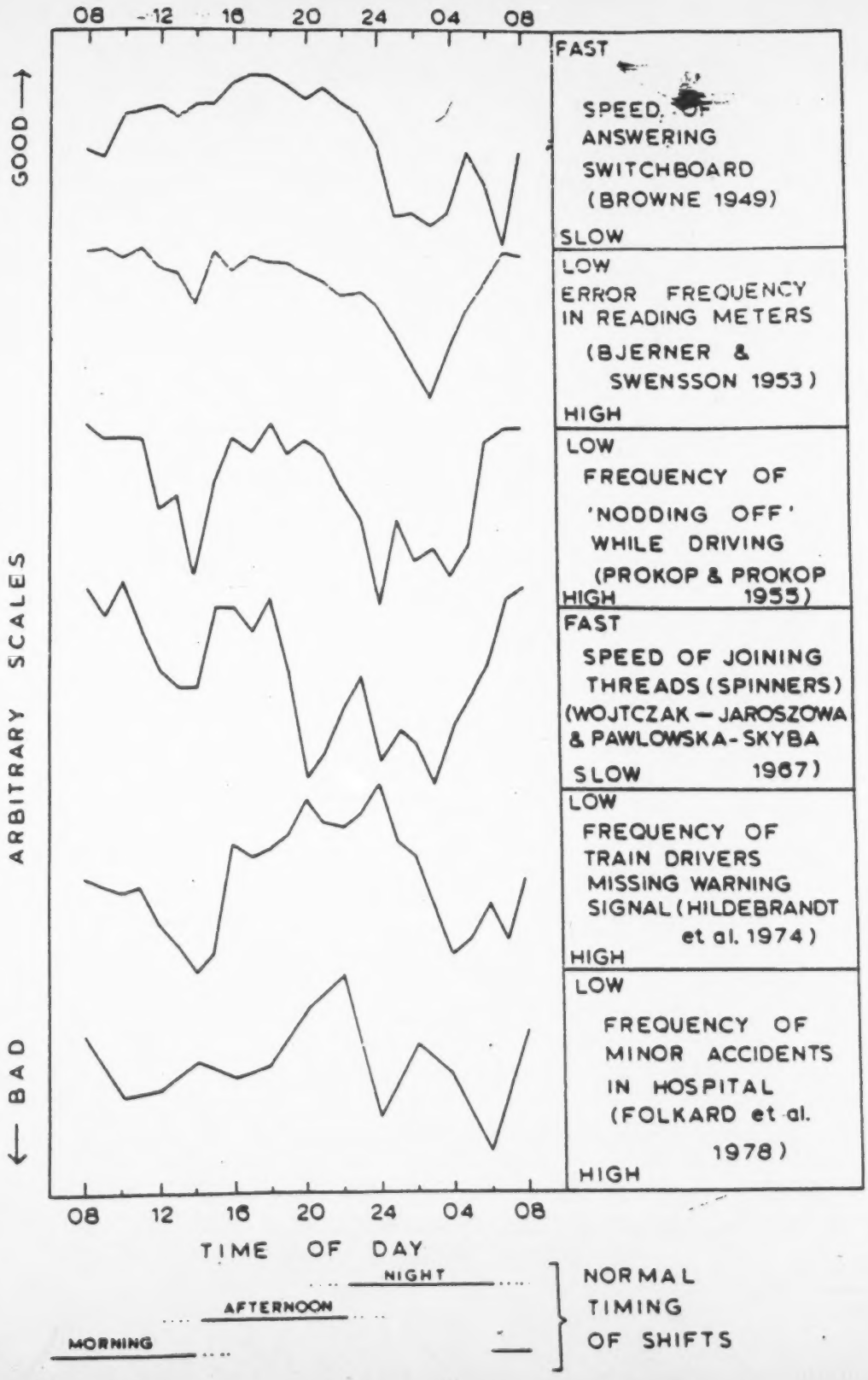

Figure 3 Variations in 'real job' measures over the 24-h period. From Folkard and Monk (1979)

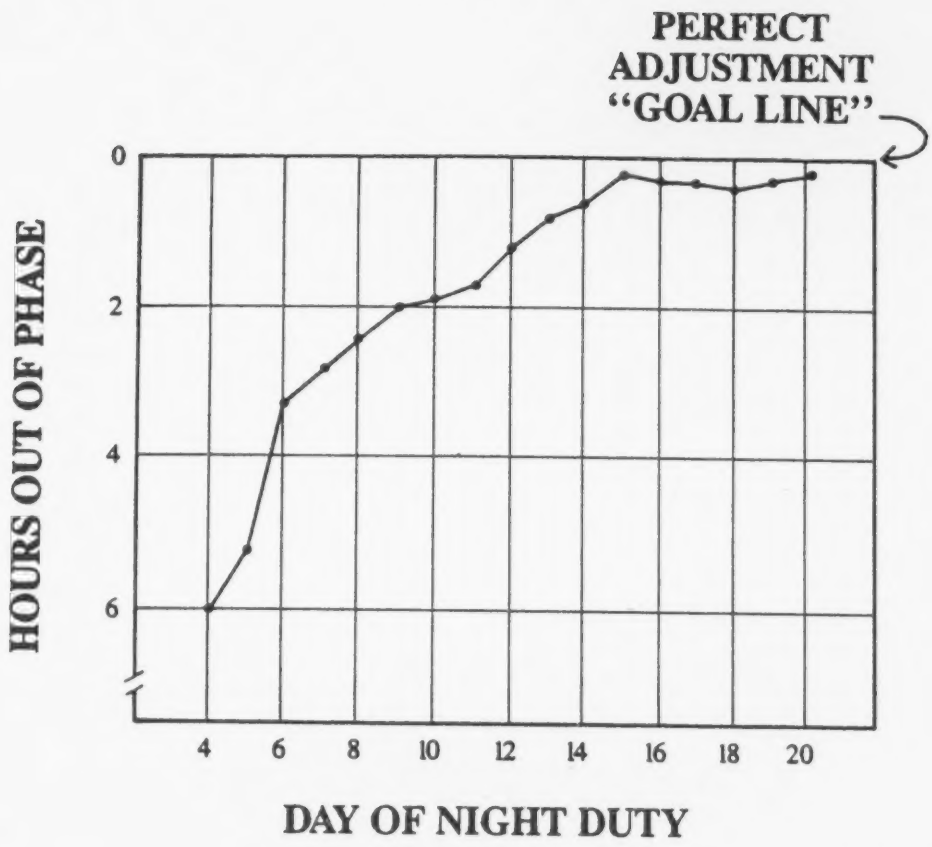

Figure 4. Average phase adjustment of rectal temperature in two volunteers working 21 consecutive night shifts (after Monk, et al., 1978).